District Heating City of Turin (Italy)

This success story is not an example of best practice in terms of cost-effective implementation of building renovation and renewables. But it is an intervention at a district scale of the energy system in a unique context that may be relevant to other similar interventions.

Country: **Italy**

Name of city/municipality: **Turin**

Title of case study: District Heating City of Turin

Year and duration of the renovation: 1982 - nowadays

Author name(s): L. Teso, T. Dalla Mora, F. Peron, P. Romagnoni
Author email(s): tdallamora@iuav.it

Link(s) to further project related information / publications, etc.:

Schematic figure or aerial overview

Turin's integrated cogeneration and district heating system is fed with the heat produced by the 3 modern combined cycle plants operating in cogeneration mode at the Moncalieri and Torino Nord stations.

Needs for supplementary power are covered by the thermal power plants of Moncalieri, Torino Nord, BIT, Mirafiori Nord and the Polytechnic.

The system is capable of **heating a volume of 60 Mm^3, covering the 55% of heat demand** in the buildings of Turin through a complex network of over 500 km, making Turin the city with the largest district heating system in Italy.

Figure 1. Schema of Turin District Heating Network, showing the two main stations and the supplementary substations for the heated area

Introduction and description of the situation before the renovation

Systems

Before the change of district heating, the residential buildings in Turin had individual heating systems. Each one was heated by individual or condominium boilers with fossil fuels, especially natural gas.

Some of the oldest buildings in the city of Turin were fed with ecoden, a fuel oil that since 2017 can no longer be used, as the Region considers it too polluting.

The first cogeneration system was installed in 1982 at “Vallette”, which was characterized by a heating power of 22 MW and it supplied 3 million m^3. Since 2011, it is not been anymore in use.

Air quality condition

The most critical pollutants in this area are nitrogen oxides, ozone and airborne PM10 powders.

In particular, for nitrogen oxides, in the last years the average annual concentration limit value (40 µg/m3) has been exceeded in all monitoring stations closest to the intervention area, as well as the hourly value of 200 $\mu g/m^3$ has been exceeded more than 18 times.

Carbon monoxide, on the other hand, is no longer a critical pollutant, since its concentrations in the atmosphere have been significantly reduced in recent decades, reaching values well below the limits prescribed by law.

Description of the renovation goal

The project aims are the containment of emissions into the atmosphere, thanks to the progressive elimination of hundreds of condominium boilers that allows to obtain a reduction in emissions of 134 tons per year of nitrogen oxides, 400 tons per year of sulphur oxides and 17 tons of harmful powders. In terms of energy, an annual **saving of 95,000 toe** (equivalent tons of oil) is achieved, in addition to the 180,000 toe years already saved thanks to the Moncalieri cogeneration plant.

The most important environmental benefit regards its potential impact, in terms of improving the air quality in the urban area, following the expansion of district heating services. The district heating service in Turin area can be extended to the northern sector of the city, with an increase in the volume of buildings served, equal to 15 million m^3.

Additional benefits include the closure of the current system “Vallette” and the reconversion of the areas due to the demolition of the power plant that makes it possible to form a continuous green belt to protect the district.

Description of the renovation concept

The main data of the Turin district heating network is summarized in Table 1.

Table 1. Main characteristics of Turin district heating network.

Heated volume	60 millions of m^3
District heating users	560,000 inhabitants
Total thermal energy delivered	2,000 GWh/y
Network extension (double pipes)	500 km
Energy saving	100,000 tep/year
CO_2 avoided emissions	300,000 ton/year
NO_x avoided emissions	134 ton/year
SO_2 avoided emissions	400 ton/year
Fine powders avoided emissions	17 ton/year
Reuse of meteoric water	yes
Condensate recovery produced by the combustion air cooling	22,000 m^3/year

The heating system is composed of two major power plant:

1- Moncalieri: it has been built in 1990 and the renovation measures, performed in 2006, consist of:

- replacement of old existing power plant with a new combined-cycle cogeneration unit (2nd GT), upgrading existing capacity from 141MW to 400MW and thermal capacity of 260MW;
- installation of second combined-cycle cogeneration unit (3rd GT) using the very latest technologies for the simultaneous production of electricity and heat.

2- Torino Nord: works started in 2011 and the project peculiarities of the intervention are:

- installation of 24 "very-low-Nox" BURNERS powered by natural gas;
- Adjustable input controls (IGV) for modulating the air flow;
- 2 combustion modes (Premix from 0 to 100% load; Pylot to stabilize the flame).

The most significant parts of the system are:

- the combined-cycle thermoelectric unit (gas turbine and steam turbine) with a gross power of about 400 MW fueled by methane;
- the 3 integration and reserve steam generators, with a total thermal capacity of 340 MW;
- the heat storage system, consisting of 6 tanks with a total useful capacity of 5000 cubic meters.

Project Fact Box (I)

General information

Parameter	unit	before renovation (1988)	after renovation (2017)
Urban scale of area:	m^2	-	-
Population in the area:	inhabitants	960,000	902,137
Number of buildings in the area		-	62,643
Heated floor area of all buildings	m^2	7,350,000	19,800,000
Heated volume	m^3	164 Mm^3	60 Mm^3
Building mix in the area:			
Residential	% of heated floor area of all buildings	62%	/
Schools		35%	/
Office buildings			/
Production hall, industrial building		3%	/
Building mix in the area:	*% of total energy use of all buildings*		
Residential		*0.55*	*0.55*
Schools		*89.5*	*89.5*
Office buildings		*7.7*	*7.7*
Public Illumination		*0.34*	*0.34*
Transport		*1.51*	*1.51*
Other buildings		*0.4*	*0.4*
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	in % of annual heat demand	10	10
Medium consumers: AB, schools, etc. – 80-800 MWh/a		90	90
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		0	0
Property situation of buildings:			
Private	% of heated floor area	-	-
Public		-	-

Property situation of energy supply system (district heating):			
Private	% of heated floor area	100	0
Public		0	100

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	**unit**	**before renovation (1988)**	**after renovation (2017)**
heating demand (calculated)	GWh/a	-	2,000
domestic hot water demand (calculated)	kWh/m²a	-	-
cooling demand (calculated)	kWh/m²a	-	-
electricity demand (calculated)	kWh/m²a	-	-
heating consumption (measured)	kWh/m²a	-	-
domestic hot water consumption (calculated)	kWh/m²a	-	-
cooling consumption (measured)	kWh/a	3,656,648	3,961,362
electricity consumption (measured)	kWh/a	11,667,430	10,266,918
(Thermal) energy supply technologies:			
decentralized oil or gas boilers	% of heated floor area	100	0
decentralized biomass boilers		-	-
decentralized heat pumps		-	-
centralized (district heating)		-	100
other *(please specify)*		-	-
renewable energy generation on-site:			
solar thermal collector area	m²	0	0
photovoltaics	Gwh	0	371.5
other (eolic)	Gwh	0	0.1

Financial issues:

Parameter	**unit**	**before renovation**	**after renovation**
total investment costs of the renovation	Euro	ca. 2 billion for power plants and networks	
- building renovation costs	Euro	-	/
- heating/cooling supply costs	Euro	-	/
- renewable energy production costs	Euro	-	/
LCC available	yes / no	no	no

Description of the technical highlight(s) and innovative approach(es)

The most recent power station of the whole system is located in North Turin, as it is following described:

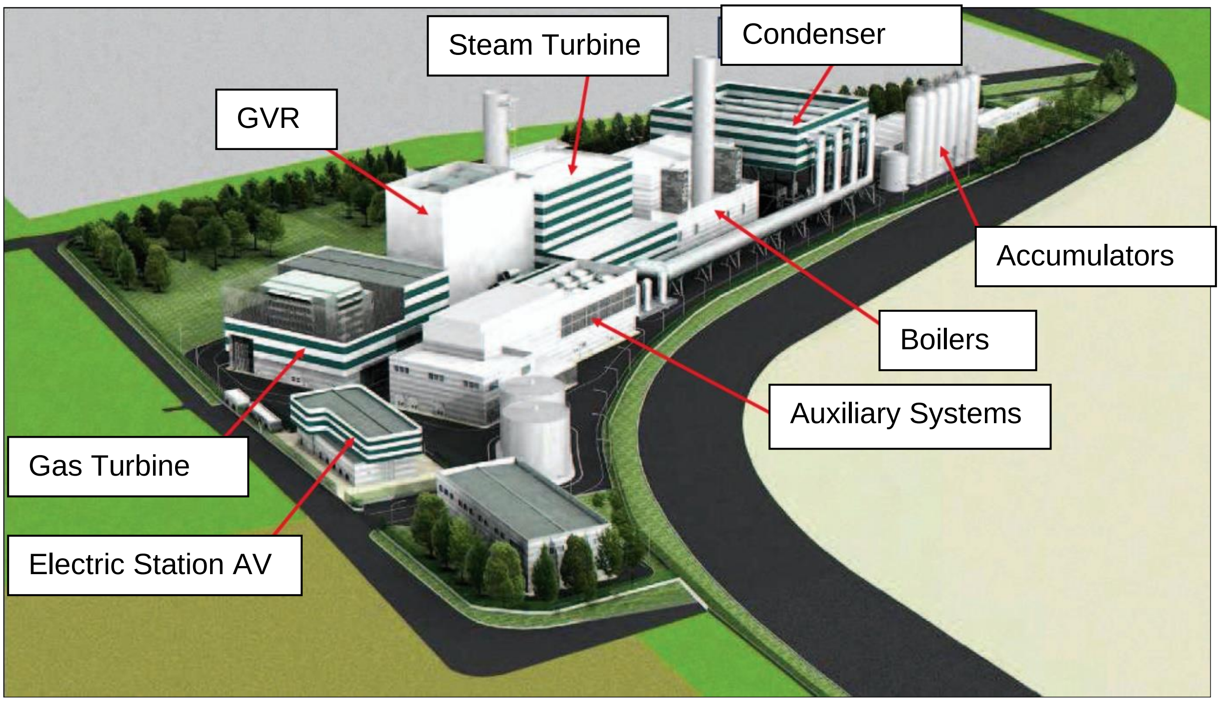

Figure 2. Schema of the new power station

The cogeneration system, which has a combined-cycle group of about 400 MW and three integration and reserve steam generators, with a total thermal capacity of 340 MW, is equipped with a **modern control room**, equipped with the most modern technological solutions available in the sector. Located on the first floor of the main building there is a main console and a back-up with 24 hours operation.

The plant is composed of the following production groups:

- 1 Combined cycle thermoelectric group in cogeneration structure;
- 3 integration boilers and district heating reserve;
- 1 Auxiliary boiler;
- 1 modern control room.

The combined cycle fueled by gas is the most efficient of this type, offering considerable advantages over traditional ones through a high efficiency (55-58%), a reduced environmental impact and a low-cost production of energy. The combined-cycle thermoelectric power system in the cogeneration structure of the power system consists of the following equipment:

- a gas turbine with an electrical power of about 250 MW, powered by natural gas, with an air-cooled electric generator, equipped with "very low NOx" burners;
- a recovery steam generator with chimney, equipped with a system to reduce emissions into the atmosphere;

- a condensation steam turbine, composed of three sections of electrical power of about 140 MW with an air-cooled electric generator, with low-pressure steam extraction for the production of superheated water for district heating;
- a condensation system for the steam and air turbine with air heater;
- heat exchanger system for district heating, with a capacity of 220 MWt, which uses the low-pressure steam tapped by the steam turbine.

Table 2. Energy production of Turin district heating network.

Electric power	390 MW (electric attitude)
	335 MW (cogeneration attitude)
District heating thermal power	220 MW
Electrical efficiency	56%
Thermal efficiency cogeneration	83%

Decision and design process

General / organizational issues:

The intervention was performed to meet the request of the inhabitants of Turin. The use of a power plant makes it possible to produce and distribute hot water and electricity to users, and there is a progressive decrease in the pollutants emitted by individual boilers using non-renewable energy sources.

Stakeholders

A total of 66 subjects were involved:

- 28 companies
- 5 research centers
- 23 institutions
- 10 non-profit associations

More than 350 participants. From the city of Turin:

- 77 persons
- 55 persons directly involved in the workgroups

Main steps

The whole intervention was possible thanks to a deep knowledge of urban development of Turin which has brought to a successful overall planning of the district heating system and allowed to build the first integrated cogeneration. Since then, it has been observed a well-run and controlled improvement over the years.

Resources available before the project

The were no resources available before the project.

Drivers and barriers (opponents)

Main driver was the wish of the municipality; opponents are not known.

Stakeholders' role and motivation:

Main stakeholder	**Specify which organization(s) was (were) involved**	**Role (decision maker, influencer, technical advisor, delivery)**	**Driver/motivation**
Policy actors (municipality department, government body, innovation agency, etc.)	[a] Municipality [b] FSU (Finanziaria Sviluppo Utilities)	[a] Decision maker [b] Financier	[a] Savings, CO_2 reduction, quality of living improvement [b] Business
Users/investors (individual owner, housing association, building managers, asset manager, project developer)			
District-related actors (Community/occupants organizations, etc.)	Territorial committees	influencer	Savings, standards improvement
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	IREN Energia AES Torino	Decision maker	Sustainable development and energy renovation. Profit
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	Politecnico di Torino Univesità di Torino	Technical advisor	To contribute with own scientific know-how to improve the system
Other intermediaries (public bodies, trade organizations, NGO's, consultancies, research institutes)	-	Technical advisor	

Design approach applied:

The design approach followed was an iterative process in which several alternatives where studied and multiple expansions have followed during the years.

This study investigated the operation of heat storage in district heating systems management. It is shown that the installation of heat storage optimizes the efficiency of the district heating system, reducing the need of heat produce by backup boilers during peak demand and increasing CHP generation. In this way, primary energy savings are obtained.

These systems are able to store heat at night-time, when demand is minimal, and to use it during the early hours of the morning, when demand is at its highest. During the daytime they can also perform further cycles of charge and discharge, but these intermediate operation cycles have low relevance because they do not affect the proportion covered by cogeneration. For these reasons the simulation modelled the behavior at night-time and during the early hours of the morning that involve the most significant amount of energy.

Technical issues:

Since Turin DH network was the first example in Italy of a city-scale intervention, there were a lot of difficulties regarding the planning and the works for the implementation of the project. The use of new technologies and the continuous planning of expansions in the network were the major challenges for the project.

Financing issues:

The society that started the project find economic limitations because of its public nature and in some cases the impossibility of expand the network.

Nowadays, in order to guarantee the growth of IREN and to ensure a unified and stable strategy, the majority shareholders – FSU (Finanziaria Sviluppo Utilities, equally controlled by the municipalities of Turin and Genoa) and the ed Enia agreement municipalities. The share held by private individuals is limited by the articles of association to a maximum of 5%.

Management issues:

There were no particular challenges in the management of the project, but as said before during the first years, the society that started the project find economic limitations because of its public nature and in some cases the impossibility of expand the network, caused by the lacking of adequate laws dealing with a new type of heating system.

Policy framework conditions:

The Industrial Union of Turin, Iren Mercato S.p.A. and Iren Energia S.p.A. have signed a framework agreement to promote district heating as an efficient, economical and sustainable energy solution for the energy upgrading of the buildings of the Metropolitan City of Turin. The agreement is part of the broader development of the Group's integrated district heating systems, in line with the 2019-2023 Business Plan and with the company strategy that leverages historical strengths such as the link with customers and relations with territories of reference and develops a distinctive value proposition based on the integration of the offer, digital channels and customer centrality.

Lessons learned

Major success factors

Organizing and realizing an accurate agenda related to improvement of environmental performance, monitoring and measuring data, supervision and strict deadlines for each area are essential elements for the successful implementation of such an intervention. Furthermore, it has been possible to reach a value of 98% of energy introduced in the network thanks to heat storage system settled into the power station and along the network.

The disadvantages of a district heating network may be the large economic cost to be incurred and the invasiveness of the laying of underground pipes.

Major bottlenecks

Since there is a very wide distribution network, in case of damage even just in one point, the number of users lacking of electricity and heating supply would be considerable.

Major lessons learned

During the system planning, it has been given great importance to reduce as much as possible the emission of pollution in the environment as well as to maximize the energy production in order to reach a wider range of users.

Aspect to be transferred

The planning methodology used in this case, which has led Turin to be the city with the largest district heating system in Italy and one of the largest in Europe.